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Exact three-dimensional static analysis of single- and multi-layered plates and shells

Salvatore Brischetto*

Abstract

This new work proposes an exact three-dimensional static analysis of plates and shells. One-layered and multilayered isotropic, orthotropic, sandwich and composite structures are investigated in terms of displacements and in-plane and out-of-plane stresses through the thickness direction. Proposed structures are completely simply-supported and a transverse normal load is applied. The proposed method is based on the 3D equilibrium equations written using general orthogonal curvilinear coordinates which are valid for spherical shells. Cylindrical shell, cylinder and plate results are obtained as particular cases of 3D spherical shell equations. All the considered structures are analyzed without any geometrical approximation. The exact solution is possible because of simply-supported boundary conditions and harmonic form for applied loads. The shell solution is based on a layer-wise approach and the second order differential equations are solved using the redouble of variables and the exponential matrix method. A preliminary validation of the model is made using reference results in the literature. Thereafter, the proposed exact 3D shell solution is employed with confidence to provide results for one-layered and multilayered plates, cylinders, cylindrical shell panels and spherical shell panels. All these geometries are analyzed via a unified and general solution, and the obtained results can be used to validate future numerical methods proposed for plates and shells (e.g., the finite element method or the differential quadrature method). Proposed results allow to remark substantial features about the thickness of the structures, their geometry, the zigzag effects of displacements, the interlaminar continuity of displacements and transverse stresses, and boundary loading conditions for stresses.

Keywords: plates and shells; 3D exact solution; layer-wise approach; exponential matrix method; static analysis; multilayered composite and sandwich structures; exact geometry.

1 Introduction

Beams, plates and shells are basic components for the structural analysis in the mechanical, aerospace and civil engineering fields. Numerical models based on these elements allow dynamic, static, free vibration, stability and stress analysis of several structures with different geometries and embedded materials, and subjected to different loading and boundary conditions. Appropriate refined numerical models allow accurate analyses with an increase of safety and a decrease of the weight. However, such numerical models need a deep validation in order to be used with confidence. Such a validation could be made by means of opportune comparisons with exact 3D shell models which have two main advantages: absence of numerical problems in the solution of equations and a complete and exhaustive description

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